Journal of the Royal Society of Arts

NO. 5002 FRIDAY, 26TH APRIL, 1957 VOL. CV

FORTHCOMING MEETINGS

WEDNESDAY, 8TH MAY, at 2.30 p.m. '*A New Grammar of Ornament?*', by Sergei Kadleigh, A.R.I.B.A., Hon.A.R.C.A., Reader in Architecture, Royal College of Art. R. W. Holland, O.B.E., M.A., M.Sc., LL.D., Chairman of the Council of the Society, will preside.

THURSDAY, 9TH MAY, at 5.15 p.m. COMMONWEALTH SECTION. '*The St. Lawrence River Power Project*', by Otto Holden, B.A.Sc., C.E., D.Eng., Chief Engineer, Hydro-Electric Power Commission of Ontario. D. Pierce, O.B.E., Deputy High Commissioner for Canada, will preside. (Tea will be served from 4.30 p.m.)

WEDNESDAY, 15TH MAY, at 2.30 p.m. TRUEMAN WOOD LECTURE. '*Science in Archæology*', by Sir Mortimer Wheeler, C.I.E., M.C., D.Litt., F.B.A., President, Society of Antiquaries. R. W. Holland, O.B.E., M.A., M.Sc., LL.D., Chairman of the Council of the Society, will preside. (*Fellows should apply for special tickets for this meeting.*)

WEDNESDAY, 22ND MAY, at 2.30 p.m. FRED COOK MEMORIAL LECTURE. '*Portuguese Painters of the Fifteenth and Sixteenth Centuries*', by Carlos de Azevedo, M.A., Curator, Lisbon National Museum of Contemporary Art. Sir Alfred Bossom, Bt., LL.D., F.R.I.B.A., J.P., M.P., a Treasurer of the Society, will preside. (The paper will be illustrated by lantern slides.)

TUESDAY, 28TH MAY, at 5.15 p.m. COMMONWEALTH SECTION. THOMAS HOLLAND MEMORIAL LECTURE. '*The Imperial Institute*', by Kenneth G. Bradley, C.M.G., Director of the Imperial Institute.

Fellows are entitled to attend any of the Society's meetings without tickets (except where otherwise stated), and may also bring two guests. When they cannot accompany their guests, Fellows may give them special passes, books of which can be obtained on application to the Secretary.

EXAMINATIONS DEPARTMENT

The address of The Society's Examinations Department is now Royal Society of Arts (Examinations Department), 18, Adam Street, Adelphi, W.C.2.

EXTENSION OF THE SOCIETY'S PREMISES

The arrows indicate the Society's additional frontage in John Adam Street. No. 18 Adam Street is round the corner at the far end of the street. The original property of the Society extends from the left of the picture as far as the left-hand arrow

After many months of careful consideration and negotiation, in which Lord Nathan has played a particularly important part, the Society has been fortunate enough to obtain a much-needed extension of its premises. Three houses, Numbers 2 and 4 John Adam Street and Number 18 Adam Street, adjacent on the east to the Society's own house and contemporary with it, being part of the Adam brothers' original Adelphi scheme, have been secured on a 99 years' lease, with an option to purchase between the 14th and 21st years.

Besides meeting its own needs, the Society is performing an important service in thus securing the preservation of what, together with its present House, makes up the most important block of the original Adelphi still remaining. Tribute should, in this connection, be paid to the vision shown by the vendor, Mr. H. H. Wingate, who when the property came on the market in 1954 decided to increase the facilities and accommodation provided by the premises and restore and enhance their architectural elegance, rather than to 'develop' the site in the current fashion. The Council also wish to acknowledge the part played by the Legal and General Assurance Society Limited in not only purchasing the property for lease to the Society but also granting it the opportunity to acquire the freehold for itself after a comparatively short period. Only so could the Society have availed itself of the present opportunity which is so unlikely to recur.

One of the rooms on the first floor of the extension which will be available for exhibitions

The restoration has been carried out at considerable cost by Mr. Wingate, and with great care to bring the three houses to their former elegance. The original ceiling decorations are in a number of the rooms, one of which is illustrated on the preceding page, and fine carved doorways, fireplaces and panelling from 'Bowood' and other buildings of the period have been installed. (Some of the fireplaces unfortunately attracted the attention of thieves while the premises were unoccupied, but have since been recovered.) An automatic lift and central heating have also been introduced.

While the first thought in the Council's mind has been to make sure of the premises while this was possible, they have been equally conscious of the Society's acute need for more space. Up to the present its Library has also had to do duty as an exhibition hall and reception room (each of these uses conflicting seriously with the other two), there has been no Council Chamber, and the facilities provided for Fellows have not been such as the Council could have desired. The extension will provide the means of improvement in all these matters, and on the upper floors of the new premises there is also a considerable extent of office space. Part of this is now occupied by the Society's Examinations Department, for which there is no accommodation in the Society's present headquarters and which has already outgrown its present premises at 28, Victoria Street, S.W.1. The remainder will be let, it is hoped, to kindred societies.

As notified above, the Examinations Department have already removed to their new quarters. The adaptation and furnishing of other parts of the premises to the Society's purposes will, of course, take some considerable thought and time.

EXHIBITION OF BURSARY DESIGNS

The exhibition of winning and commended designs in the 1956 Industrial Art Bursaries Competition will be held in the Society's House from Wednesday, 21st May until Friday, 7th June. The exhibition will be open on Mondays to Fridays from 10 a.m. to 5.30 p.m., and on Saturdays from 10 a.m. to 12.30 p.m.

Special cards of admission will be required for the opening, which will be performed by Sir Colin Anderson, Des. R.C.A., at 12.15 p.m. on 21st May. It is hoped that, although the majority of these must be issued to those who are directly concerned with the organization of the Competition, a number of cards may be available for other Fellows, and those interested should apply to the Secretary by 14th May.

THE DEVELOPMENT AND USE OF GLASS FIBRES

A paper by

A. HUDSON DAVIES, O.B.E., M.A.,

Managing Director of Fibreglass, Ltd., read to the Society on Wednesday, 13th February, 1957, with W. J. Worboys, B.Sc., D.Phil, Chairman, Council of Industrial Design, and a Director of Imperial Chemical Industries, Ltd., in the Chair

THE CHAIRMAN: In the years since the War, or perhaps a little earlier, industry has presented us with a number of novel and sometimes unique products—products possessing very special properties—such as plastics, and the man-made or synthetic fibres. These are materials which in many cases are of high prime cost but possessing as they do very desirable properties they are finding increasing uses. One of these we are going to hear about this afternoon. It is a plastic because glass is perhaps the oldest of plastics. It is drawn into fibre form, and it is available both as staple fibre and as continuous filament.

We are going to hear of it from my old friend Mr. Hudson Davies and from no better source could we hear about it, because he has been since the War the managing director of Fibreglass Limited and this has been through a period of very rapid and very material progress with this interesting material. He is a wise man as well as a knowledgable man; he has covered his raw materials supply and his basic technology, glass, by becoming a director of Pilkingtons. And he has brought to his present field of activity a great deal of earlier experience in a variety of industry. I could not possibly mention all his industrial experience, but cement and rubber, heavy chemicals, even banking and the control of labour during the War, have all added to the total experience which he has put into the development of 'Fibreglass'. That in itself was all backed by the study of the natural sciences at Cambridge University. How good he was at natural sciences I leave you to determine; it has always interested me that his first job in industry was as an industrial psychologist and that was when I first met him, nearly thirty years ago now.

The following paper, which was illustrated by lantern slides, was then read.

THE PAPER

It is a daily job in a modern glass works to draw a sample for determining the softening point of a batch of glass. An operator dips a metal rod into a pot of molten glass and lifts it out again with the glass sticking to it. Just like toffee, the glass pulls out and 'freezes' into a fibre, and from this fibre a sample length is cut for the softening point tests. The operator is doing every day exactly what the Egyptians did more than 3,000 years ago when they discovered glass-fibres, and used them to make the first glass vessels in history. They made a small clay former which they stuck on the end of a metal rod; they drew a fibre; and then with careful heating they wrapped the fibre in a spiral round the clay,

covering it from end to end. They re-heated the wrapped core until the spirals of fibre melted into a continuous glaze, which was then decorated with more white and yellow glass-fibres, pulled into patterns with a metal comb while the glass was plastic. After that they scooped out the clay core, and a hollow glass vessel was left. These jars were very small—only three or four inches high, and they must have taken so long to make that they could only be articles of high luxury, but manufacture went on in North Africa for at least 1500 years, because this was the only way a glass container could be made until glass-blowing was invented in the first century B.C.

This invention was remarkable enough. It is more remarkable that, after this 1500 year run in ancient times, 1900 years of our own era had to go by before anyone found another use for glass-fibres. Fibres went on being used for decorating glassware. Romans, Arabs, Syrians, Venetians, Germans—the glass-fibre was a standard 'gimmick' of the glassmakers' art, and in the nineteenth century came to be almost a familiar curiosity. In St. Helens glass ties were woven in the colours of the St. Helens football club. Around Bristol a hundred years ago they made mantelpiece ornaments—glass birds with drooping tails of coloured glass-fibres. These were only intended to be toys, but there is delicate craftsmanship, and almost a classical feeling, in some of the best examples.

The processes which made these little jars in antiquity; these decorations in the Christian era; these toys in the nineteenth century, are the beginnings of an industry which suddenly in the last 25 years has spread all over the world. The world output of glass-fibres last year was more than half a million tons, and the industry employs about 25,000 people.

Glass-fibres as used to-day vary in diameter from 8-thousandths—used for air filters—to 300-thousandths of an inch in the very lightest insulation which is fixed inside the skin of airliners to protect the passengers from cold and noise. Glass-wool, which accounts for most of the tonnage, has fibres about two inches long. By contrast, Continuous Filament fibres are ten miles long. These are the fibres—what properties are there to exploit?

Some of the properties come from the parent glass. Glass is chemically pretty inert; it is almost completely elastic: it is a good dielectric; it is not much affected by temperature up to its softening point; it is completely non-inflammable. It can be immensely strong in tension, and this may be the most important property for the future of the industry. Solid lumps of glass do not show this property because the surface always has minute faults and cracks which cause stress concentration and premature failure in tension. Perhaps the sudden freezing of the fibres discourages the production of these small faults: perhaps too, in the fibre-drawing process, long molecules get pulled into line, as with nylon and 'Terylene'. Whatever the reasons, the tensile strength of a freshly drawn glass-fibre is of the order of 200 tons per square inch—about the same as steel piano wire.

This very great strength of a virgin fibre is soon lost through exposure and through handling, but even when it has diminished to the normal eighty tons per square inch of commercial glass yarn, this is still stronger than ordinary

steel. The low specific gravity of glass, which is about the same as that of aluminium, gives glass-fibres a strength-for-weight ratio which is the highest of any known material. High electrical and heat resistance, great specific tensile strength, chemical stability—these are the properties which are exploited in glass-fibre applications.

MANUFACTURE OF GLASS-FIBRES

A glass-fibre is made by pulling out the viscous glass. The pull can be applied either directly, or by the friction of a rapid stream of gas. The simplest pull is the direct draw as for the softening-point test; the most ingenious was the classic method of Professor Boys. When he was Demonstrator of Physics in the Science Schools, South Kensington, in 1887, he wrote a paper called 'On the Production, Properties, and Some Suggested Uses of the Finest Threads'—not far from the title of this paper seventy years later. Boys' method was this. He fixed a piece of glass to a small arrow in a crossbow. He melted the glass with an oxy-hydrogen flame and when it was just melting he pulled the trigger, and away flew the arrow along his laboratory leaving a fibre behind. He managed to make glass fibres ninety feet long and one ten-thousandths of an inch in diameter. He must have been a happy man. In his paper he points out that a rocket, with an acceleration of 28g, would have been considerably better than the crossbow—but not really so comfortable in a small laboratory. This method is not used to-day, but it shows some of the elements of the fibre-making process. The essence of the job is to get the glass to the drawing point at the right temperature, to develop and apply the right force, and to get the attenuation described in the very short time that the glass is in the viscous range, between completely fluid and completely solid.

There are many practical ways of doing this. From 1900 onwards fibres were wound on wheels or drums out of refractory furnaces through holes bored in the refractories. The Germans were the most active inventors at that time, and made glass silk as a substitute for asbestos in the First World War. This was the system used by Chance Brothers in 1930 when they established the first commercial manufacture of glass-fibres in Great Britain.

Though there are vigorous and promising European processes to-day, the major part of present world production depends on two methods originally developed in the United States—the Owens-Corning processes for Wool and for Continuous Filament.

WOOL MANUFACTURE

Glass wool is the big tonnage product. The raw materials of glass—sand, lime and soda, are ground finely and fed into a continuous furnace where a temperature of 1400°C. is reached. When the finished glass reaches the end of the furnace it runs into a number of small platinum vessels or bushings about 12 inches × 9 inches × 6 inches in size, with at the bottom 32 tips, each carefully dimensioned and profiled. There are about twenty of them on a typical wool plant. The platinum bushing is heated by electric current and represents the

FIGURE 1. *Fibre shattering*

last correction point for temperature, which has to be very accurate at this stage in order to control the exact viscosity of the glass. From each tip flows a small stream of glass, by gravity. As it falls, within an inch it is caught in a blast of superheated steam. The high speed of the steam blast grasps the tiny glass stream, and by a whipping and worrying action which can be seen on high-speed photographs, the steam frays out the stream of glass, and drags out a filament until it breaks away from the stream and falls as a separate fibre into the collecting hood. (See Figure 1.)

Binders of various kinds—resin, stearin, bitumen are sprayed on to the fibres as they fall. A mat of fibre collects below on a conveyor and is carried away, first through curing ovens to dry and set the binding agents, and then away to trimmers and guillotines which shape the final product. (See Figure 2.)

WOOL APPLICATIONS

Wool fibres are single fibres about two inches long on average, and they pack together in a springy mass like cotton wool. This, of course, means insulation, because such a mass of fibres encloses millions of small air cells—indeed, some say the job of a glass-fibre maker is to pack up 98 per cent of air with two per cent of glass and sell the result to the public at a premium! Glass-fibres for insulation run into many thousands of tons a year in this country alone—in houses and factories, in ships and caravans, on boilers and process plant. Because of the light weight and the complete immunity from fire, every

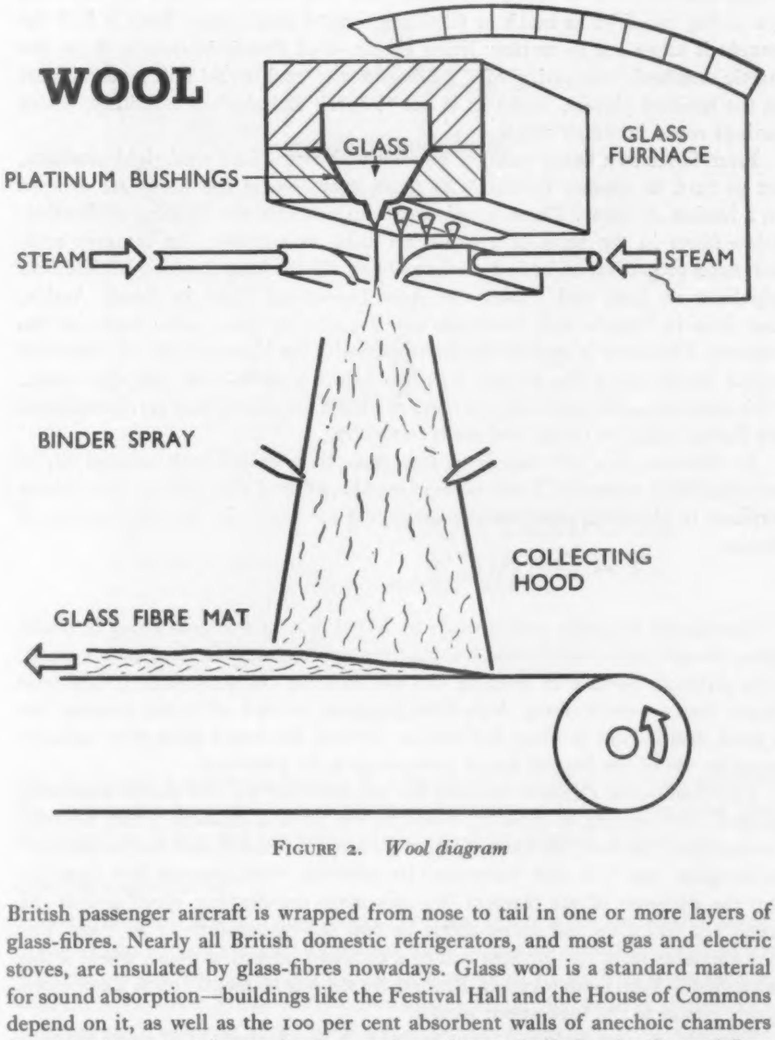

FIGURE 2. *Wool diagram*

British passenger aircraft is wrapped from nose to tail in one or more layers of glass-fibres. Nearly all British domestic refrigerators, and most gas and electric stoves, are insulated by glass-fibres nowadays. Glass wool is a standard material for sound absorption—buildings like the Festival Hall and the House of Commons depend on it, as well as the 100 per cent absorbent walls of anechoic chambers for research on sound reproduction, such as the one built for the General Post Office. The glass-fibre sound absorbent is packed into wedge-shaped elements which project towards the working space in the centre of the room, and kill all sound reflection.

The house insulation market is only partly developed. Not one house in twenty has even roof insulation at present. A high proportion of local authority housing built since the War fails to meet the standards of the Egerton Report. Yet we have

a total national stock of 11 million houses, and if all these were properly insulated the saving could be as much as 6 million tons of coal a year. Even if half the benefit is taken out in warmer living rooms—and British bedrooms above the Arctic standard—the saving of 3 million tons of coal would still be significant in the national picture. And this is not to speak of industrial buildings, where savings could be much more.

From fibres as a fleecy mass, or bonded with resins into semi-rigid products, let us turn to another derivative of glass-wool—where the fibres are arrayed in a lamina or tissue. There is only space to describe one striking application. Glass-fibres in the form of a tissue are used to reinforce the bitumen anti-corrosion protection on buried steel pipelines. All the long-distance Middle East pipelines in Iraq and Syria, the American-owned lines in Saudi Arabia, and lines in Canada and Venezuela are wrapped in glass tissue made in this country. The tissue is applied simultaneously with the bitumen coat, by a machine which travels along the welded pipe just before it is lowered into the trench. This same tissue is used more and more as a basis for roofing felts and membranes for lining irrigation canals and earth reservoirs.

Air filtration is a job done by coarse glass-fibres coated with mineral oil, in an expendable assembly. These coarse fibres have found other uses as interchange surfaces in chemical plant, and as a support for media in the manufacture of biotics.

GLASS YARN MANUFACTURE

Continuous Filament yarn is made by direct pulling from a bushing in which glass, already made and formed into marbles, is remelted (see diagram Figure 3). The platinum furnace or bushing is a job of great craftsmanship. It is a little larger than a wool bushing. Very little platinum is used up in the process, but a great deal is held in plant and spares—indeed, the world glass-fibre industry must be one of the biggest single commitments for platinum.

The Continuous Filament bushing has 204 forming tips, and each is accurately shaped. The amount of glass delivered by the tip is a constant which depends on the size of the hole, the head of liquid glass in the furnace, and the temperature of the glass, which in turn determines its viscosity. With constant flow from the tip, the diameter of the filament depends upon the drawing speed and at the usual 100 feet a second drops down to two ten-thousandths of an inch. The 204 filaments from the bushing run to a common collecting point, where a size is applied to keep them together. From there the 204 filaments run as a combined single strand to the high-speed winder.

There is one non-technical point to make. A hundredweight of single filament would stretch to the moon and back, and if anyone complains about prices—(and misguided people sometimes do!)—the tactless answer is that if they can go away and make a glass rod ten miles long, two ten-thousandths of an inch in diameter, and circular to within ten per cent anywhere, and sell it for a farthing, as our industry does—well they are most welcome to do so!

From the winder the strand goes on to be treated exactly like a normal textile

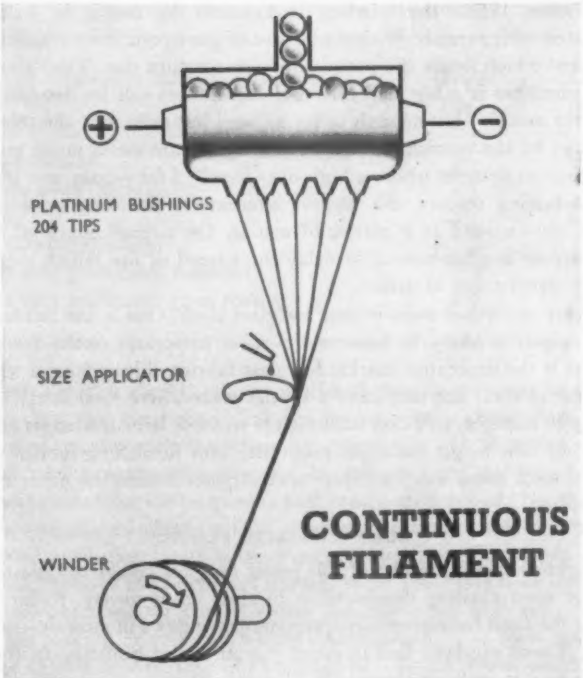

FIGURE 3.

yarn on standard textile machinery. It is twisted and doubled and then passes to the cable and wire makers, or to the firms of weavers and finishers who have pioneered the design and marketing of glass cloth in its many applications.

Glass yarn applications

Five glass yarns still find their most important outlets in the electrical industry. For electrical purposes a special glass has to be used with an alkali content of less than one per cent instead of the normal 15 per cent of a soda lime glass, because we must be sure that if moisture gets into the insulation of a motor or transformer, it cannot leach soda out of the glass and so become a conducting electrolyte and cause the insulation to break down.

The resistance of glass and its stability to temperature make it the best insulator for all equipment in which the designer wants to be free to accept a high temperature in the windings—for example, because he wants to save weight, or because he expects to meet overload conditions. Glass yarn and braided sleeves are used to cover the conductors; glass cloth goes into the lining of the slots and the separation of the coils. Glass cord is used to tie down the ends of the leads from

the segments. When the winding is finished the motor or transformer is impregnated with varnish. With the advent of glass yarn, the varnish has become the element which limits the permissible temperature rise. The development of silicone varnishes is a big step forward, and motors can be designed to-day to run at over 200°C.—hot enough to fry an egg, but even now the temperature is still limited by the varnish: the glass windings would stand much more. Nearly all electrical equipment where a high duty is called for—train and tram motors, aircraft actuating motors, the biggest alternators, the motors for steel rolling mills—is glass-wound as a matter of course. On aircraft much of the normal electric wiring is glass-wound to delay the spread of fire which might put the operating circuits out of action.

There are two other main outlets for glass cloth. One is the reinforcement of plastics, which is likely to become the most important outlet for glass yarn. The other is the decorative market for glass fabrics. These fabrics will never be suitable for clothes, but they have a special place where total safety against fire, immunity to sunlight, and easy washing are wanted. British weavers and finishers are learning how to get the right properties into furnishing fabrics made from glass, and soon these will take their special place beside the other materials of the trade.

GLASS-REINFORCED PLASTICS

It is right to spend the rest of this paper on glass-reinforced plastics because this is the most exciting development in glass-fibres to-day. Radar in the War produced the need for electrically transparent windows in aircraft—the so-called radomes. These windows had to stand vibration and buffeting in the air: they had to be easy to make in shapes like blisters with two curvatures: and they had to be very accurate in dimensions. No existing materials exactly fitted this need, but the problem was solved by reinforcing the new polyester resins with glass cloth, which was the answer for two reasons—its electrical properties and its strength.

This turned out to be the beginning of a new structural material which has developed rapidly in the last ten years. Of course, resin/glass structures are not the only reinforced plastics. Paper and cloth have been commonly used for fifty years since Baekeland's time, and asbestos fibres are also used to-day for structural plastics, especially in conjunction with thermosetting resins. What is new is the polyester resin which polymerizes without releasing water, so that only small moulding pressures are needed; and new also is the glass-fibre, made and presented in the forms required for moulding and for the development of strength in the reinforced plastic end-product.

Most resins have good strength in compression, but they are poor in tension, and rather brittle. When glass-fibres are married with a resin they do the job which steel does in reinforced concrete. Glass-reinforced plastics are extremely strong and also extremely light. A very crude way of comparing them with some other high-duty materials is to think what is the weight, and what is the cost of a rod 12 inches long designed as a link to support a weight of 100 tons.

TABLE I

12-inch rod to carry 100 tons	*Weight (lbs.)*	*Cost (pence)*
Steel (high tensile)	7·3	64
Aluminium alloy (high duty)	4·3	190
Titanium	2·5	4,600
Glass-reinforced plastics:		
60 per cent glass cloth laminate	4·0	460
70 per cent orientated glass roving	1·6	73

This is what Table I shows, taking published tensile strengths and present prices. It is clear that the lightest link for the purpose is the seventy per cent glass-reinforced plastic with the fibres all running in the direction of stress. This weighs 1·6 lbs. against titanium 2·5 lbs. and steel 7·3 lbs. Now looking at cost, the cheapest link for the purpose is high tensile steel at 64*d.*, but the seventy per cent glass-reinforced plastic runs it close at 73*d.* This Table does not show that glass-reinforced plastics are better than anything else. For certain purposes the virtues of titanium are worth any money. What the Table does show is that resin/glass laminates are right on the map amongst other high duty materials, when you are looking at cost and weight and strength. The right material for a job will be chosen on a balance of advantage of function, costs, weight, ease of design and ease of manufacture, and any one of these in a particular application may quite overwhelm the comparisons of the oversimplified Table I.

One such advantage for glass-reinforced plastics is that they are in some ways much more easily shaped than metals. They can often be moulded simply without the use of heat or tooling; and integral structures of considerable size can be built up—for example, a boat 100-feet long all in one piece.

Let us mention some of the other advantages of the glass-reinforced plastic, and also some of the limitations to give a balanced view. On the asset side, both resins and glass are relatively inert substances—the exact resin and the exact glass have sometimes to be chosen to suit the conditions, but neither of them are affected by ordinary causes of deterioration such as corrosion in metals or decay in wood and so they need no maintenance. They can be made translucent; they withstand 100°C. readily, while special resins are used for radomes up to 200°C. At these temperatures there is little loss of strength, and as far as we can see at present, creep and fatigue effects are small. Newer resins, such as the epoxides and the silicones, are helping to widen the range of properties.

The debit side is mostly sheer lack of knowledge. After all, this unorthodox material is just over ten years old and everyone is feeling out the way. We suffer almost from an *embarras de richesses*. New resin formulations are being produced every week: old ones get out of date. New manufacturing methods develop:

new applications open, so that the young industry is in constant change. This means that systematic data are apt to be neither full enough, nor well enough documented. The designer has to gather bits and pieces of information from published literature, and from manufacturers of fibres and resins; the moulder has to make his own trials and standardize his working methods. We are still far from the day when resin/glass laminates achieve predictable, consistent properties within well-defined limits of performance, where designers and manufacturers can accept them as vernacular and can cut down safety factors which are really factors of ignorance. When this stage is reached, reinforced plastics will be used with what, on the other side of the Atlantic, is called 'imagineering'—that fertile union of imagination and firm knowledge which opens the broad advance.

Work has gone far enough in some fields for this condition to be approached. It is significant that the aircraft industry is such a field. The problems of the aircraft designer are so many and so acute that any new material with promise must be exploited quickly. It is not an accident that glass-reinforced plastics began with radomes, and it is not an accident that tail fins, wing tips, propeller spinners, de-icing equipment, hot-air ducting, and many cabin details have already been standardized in resin/glass. An air starting bottle for gas turbines already operates at 3,000 lbs. per square inch, and is an accepted item. The day of load-bearing components such as wings in reinforced plastics is probably not far off—and they hold out the promise of being much cheaper to make.

Costs

A limitation which is passing is cost. The demand for a new structural material is closely conditioned by the price, and often proves to be highly elastic once the price falls with development. Only six years ago in 1950, the cheapest glass-fibre reinforcement for plastics cost 15*s*. per lb. In 1956 the cheapest price of a well-established product is under 4*s*. per lb.—about a quarter. Resin prices have fallen in the same way and so, in spite of the lack of knowledge and the other limitations, the applications of glass-reinforced plastics are growing quickly.

Moulding methods

The methods used for moulding vary from laying up by hand on formers, where layers of glass cloth, or glass-fibre mat, are put into place in varying thicknesses according to the strength required. Here is another advantage of glass reinforcement—again just like steel in concrete—the reinforcement can be arranged in the directions of stress and can be varied according to need. When the glass-fibres have been laid on the former, they are impregnated with resin, sometimes by hand methods, sometimes by vacuum or pressure, and this is followed by curing, either cold or at moderate temperatures. This is a sort of fly-paper and treacle technique which looks very primitive, but it is cheap, and it gets results within tolerable limits on many different jobs.

Most present-day resins set by chemical change and time has to be allowed for setting. This is a disadvantage, because it means waiting about, and an

expensive use of floor space, especially for large objects like car bodies where the alternative is steel sheets which can be pressed out at two a minute on the area taken up by a big press. These delays matter greatly for the big motor-car manufacturer, but they are, on the other hand, no bother at all to the boat builder whose present methods are slow and space-consuming anyway.

When we come to the other end of the size range, to miners' helmets, ammunition boxes, battery cases, typewriter covers, and any small objects with compound curvature which need lightness and strength, these can be moulded hot in metal press tools after the chopped glass-fibres for reinforcement have been made into a 'preform'—rather like the 'hood' from which a felt hat is made, and on the same kind of machinery.

Applications of glass-reinforced plastics

Amongst present uses, corrugated translucent roof panels, which match in with the ordinary corrugated steel or asbestos roofing sheets, take about thirty per cent of the market: boats from dinghies to cruisers take about ten per cent: military uses and aircraft take thirty per cent, and commercial vehicles, including public transport, about 12 per cent. This balance will obviously change as time goes by.

Developments in public transport are important. The requirement for a bus body is strength, easy repair and light-weight, with, of course, some regard to cheapness. A major bus company—the Birmingham and Midland Motor Omnibus Company—have for some time been making body components in their own workshops from resin/glass (see Figure 4 overleaf), and here are some actual comparisons of cost and weight on specimen parts:

TABLE II

	Price		*Weight*	
	Aluminium sheet	*Glass-reinforced plastics*	*Aluminium sheet*	*Glass-reinforced plastics*
	£ s.	£ s.	(lbs.)	(lbs.)
Front dome	13 5	6 9	40	31
Cab partition ...	8 14	3 5	25	15
O/S front wheel box	4 6	2 5	21	12

A batch of buses is never big enough to justify heavy tooling—most of the aluminium panels have to be beaten up by hand from sheet. Take the top line, for example. The dome which carries the destination panel weighs forty lbs. in aluminium and costs £13 5*s*. 0*d*. In resin/glass it weighs 31 lbs. and costs

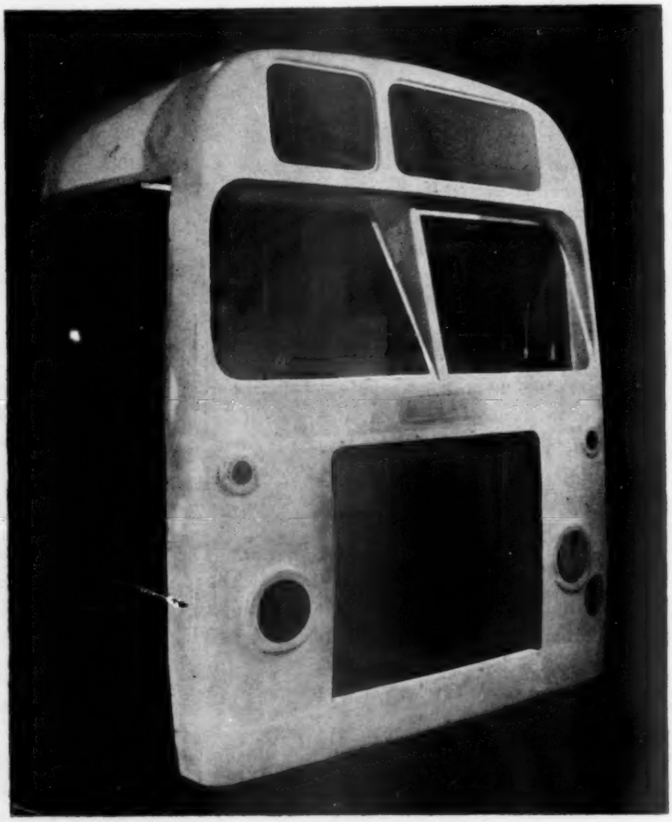

FIGURE 4. *Bus front, moulded in 'Filreglass' Reinforced Plastics, by the Birmingham and Midland Motor Omnibus Company Ltd.*

*£*6 9*s*. 0*d*.—three-quarters of the weight and half the money. When it is considered that a bump easily dents and disfigures an aluminium panel, whereas a resin/glass panel is much tougher, the advantage of resin/glass is obvious. If the panel has to be repaired after a severe blow the damaged area is cut out, and the hole is filled with those glass-fibres soaked in resin which sets and builds up solid with the main structure. Time off-the-road is saved because this can be done without dismantling the body. After this investigation 270 buses with no less than 92 components in resin/glass, including the whole of the front of the bus have gone into service.

Much of the bodywork of a lorry can be made in resin/glass. A body with the roof made in a translucent laminate which allows bright daylight inside is most

popular for pantechnicons. In using reinforced plastics for vehicle work at present, the practice is to clothe an orthodox load-bearing framework of wood or metal with resin/glass components, but this is a transition stage. Caravans are the first vehicles in which the builders have begun to exploit the strength and the monolithic moulding properties of the reinforced plastics by working with a stressed skin construction. There are about 3,000 lorries and 2,500 buses with considerable areas of resin/glass panel on the roads of Britain at present.

FIGURE 5. *The* Perpetua

Reinforced plastics are a 'natural' for boats, especially because of the lightweight, and the resistence to rot, corrosion, and marine boring worms, and something like 2,000 boats have been moulded in this country up to date. Perhaps the most impressive achievement is the 54-foot hull built by Halmatic Limited of Portsmouth (see Figure 5). A hull of this size is about as cheap to make in reinforced plastics as in wood, though for smaller craft the plastic hull is a little more expensive than a wooden one.

In the last two years ships' lifeboats have been made in reinforced plastics, and there are now 300 of these in service or on order. The most popular size is 24 feet long, holding 48 people. At this size they cost about twenty per cent more than the equivalent aluminium boat, but they score on weight, on maintenance, and even on fire resistance, according to Ministry of Transport tests.

Because resin/glass has good chemical resistance, electro-plating tanks and chemical fume ducts are being made. Several firms are experimenting with pipe manufacture. A four-inch diameter reinforced plastic pipe is twice as dear as a mild steel pipe, but it is seventy per cent cheaper than stainless steel. There are difficulties about porosity at present but reinforced plastic pipes are already in use for low-pressure pumping of corrosive liquids such as brine.

Development needs

Problems develop as fast as applications. What are the targets for improving glass resin laminates? The thermosetting resins must cure more quickly. Cures at 200°F. and fifty lbs. pressure for three minutes are the target. If we could use thermoplastic resins with a 15-second moulding time this would be a great step. For aircraft use, laminates must show high strength retention at 250°C. Laminates must be more resistant to water, especially at high temperatures. Resistance to fire is important, and though there are already fire-resistant types of resin which do not support combustion, we must try to find resins which are absolutely non-combustible. Improved methods of joining metals to mouldings, and mouldings to mouldings need to be worked out. And full data under all conditions are needed by the designer before resin/glass laminates can become part of his ordinary vocabulary.

The glass-fibre maker has to make his fibres cheaper; he has to produce fibres in new compositions—for example, to improve resistance to chemical attack and to improve the stiffness of the fibres. Above all there is the problem of the glass surface, and of the adhesion of the resin. The linkage formed between the resin and the glass is of fundamental importance. Some slipping under stress may help: too much can mean that strength is not developed in the laminate. So the surface of the fibre, and the use of coupling agents such as silane, or chrome materials between the resin and the glass are under intensive study. Finally, the manufacturer of fibres also has to consider the presentation of the fibres to the moulder, whether as yarn, cloth, loose chopped fibres, and mats made from them. Already there are many products—but more will be demanded.

Future

Where will glass-reinforced plastics fit in twenty years from now? Twenty years is a reasonable time for a new industrial notion to establish itself—think of stainless steel, or think of welding as a structural process. By 1976 complicated structures such as railway passenger coaches, buses, aircraft, will commonly be made in glass-reinforced plastics. Ships bigger than 100 feet long are possible and even for much bigger vessels, parts such as deck houses and upperworks will be made in glass-reinforced plastics because light weight especially above the water line, is more and more required by the ship-building industry. For buildings, roof-lighting will be a commonplace, and laminates may offer the way to completely prefabricated walls embodying weather-skin, insulation, and an internal finish in one integral standardized component. The complete roof structure in one piece is possible.

By then there will, of course, be new resins, and maybe even new reinforcements such as metal fibres, or new synthetic fibres. Or the fibres may for some purposes be replaced by glass flakes, like mica. But in an expanding field of opportunity it is likely that glass-fibres will hold their place. Nearly always a new material is first thought about and designed as if it were an old material. The combination of strength and plastic qualities in design, and in moulding and joining processes, so that big monolithic structures can be made, is a new one. In time it will create new habits of thought; but new jumps of the imagination will also be required before the possibilities can be fully realized and fully used.

CONCLUSION

These are a few of the high-lights in the application of glass-fibres—there are many more products and many more uses. But it is very difficult to think of a single field of use where glass-fibres are the only answer. In the insulation of buildings, ships, boilers, there are many useful materials which were accepted long before glass-fibres, and some which have come along since. One could mention slag wool, cork, vegetable fibre board, aluminium foil, asbestos, magnesia, and lately, foamed plastics. As a base for roofing felt and pipewrap, jute was king once. In the electrical industry paper, silk, nylon, cotton and rubber jockey for position with glass-fibres. Whichever way the fibre-maker turns he has an established rival, determined not to be pushed out. And not only is there competition against other products for established markets and for new ones, but the young glass-fibre industry, with several well-backed concerns, is highly competitive within itself. This is a healthy climate for progress.

Of course, competition is not the only way to progress. Co-operation is sometimes even more important for, as you will have gathered, many applications of glass-fibres involve knowing someone else's field most intimately—seeing his problems through glass-fibre eyes! This business of trying to understand the needs of so many different users, with so many completely different technical problems, can be something of a strain on a small industry with limited manpower, but it is what produces the advances you have heard about. The customers, the research groups of other industries, the cloth weavers, the resin makers—their enterprise and co-operation is just as important as the research and development of glass-fibre makers. It is only by intensive development work, by market research, by strict technical control, and by straight price challenge that suitable fields can be identified and captured. For whatever technical interest, whatever glamour glass-fibres may have, the fundamental question which the customer asks is 'What will this product do for me, and what does it cost?'

The major impression left on me by this paper is of the sudden multiplication of uses for glass-fibres in the last 25 years after more than 3,000 years of gestation. This new industry must hold the all-time record for slowness of development from the stage of invention to the stage of commercial exploitation. But the present rapid advance is not untypical of the glass industry as a whole to-day.

Glass has for long been taken for granted as one of the basic products of civilization. It has always been one of the most accessible, most durable and potentially one of the cheapest materials available. We are beginning to look with fresh eyes on its properties and its value in the world of to-morrow. The development and use of glass-fibres may be a sign of things to come.

DISCUSSION

BRIGADIER J. L. P. MACNAIR: When during the War we were investigating the German V 2, that was surrounded by glass-fibres, a great deal of care had always to be taken in examining these because we understood that, if you touched them, you were liable to get glass splinters in your hands and body. I would like to ask the lecturer how that position has altered, because obviously these glass-fibres cannot be of any danger now, but what is the difference? He mentioned in the course of his lecture that glass fibres would not be used for clothing. I would like him to amplify that: why should they not be used for clothing, what difference is there, for example, from another synthetic fabric; is there any question of splinters?

One of my companies is very interested in producing very fine powders by special aerodynamic process for plastic fillers. So far we have not had much to do with glass, but we have been approached by one firm who asked us to make highly-pulverized glass for plastic fillers. Now, of course, the lecturer has told us about the use of glass-fibres more in the shape of mats on which the fibres can be laid in the requisite position. I would like to ask him whether, supposing those fibres were broken down, as we can break them down, to micronic size and laid out by means of a process which is the very opposite to grinding—it tears the fibres apart with the result that you produce for every particle of size an immensely increased surface area, which is, of course, the most important thing from the point of view of the filler—could such a particle size be of value? It is a thing on which we have been doing a great deal of research.

THE LECTURER: Why are glass yarns not suitable for clothing fabrics? The answer is that glass yarn is very subject to abrasion and only a little rubbing will make a hole in an unprotected glass cloth. The glass fibres are very small in diameter and the pressures between them when you squeeze them together become colossal, so that they cut through each other. Now that does not affect curtains, because they are at rest when they hang normally, and a glass cloth will stand the ordinary pulling to and fro of curtains. There is nothing abnormal about its life as a curtain material, but in clothes you get constant shearing action when you move and the fibre abrades. Why have fibres become less irritating nowadays? The reason is that the whole object of a glass-fibre maker is to make his fibres finer, and since the War big strides have been made in reducing the diameter of the fibres. The fibres for insulating the V 2 were probably more than seven ten-thousandths of an inch in diameter, whereas now we are working around two or three ten-thousandths and this reduction in average diameter makes a great deal of difference to the irritation. On the last point, I think that if a glass is powdered it just becomes a mechanical filler like any other hard powder. It is when the glass is in the form of a fibre that you get the possibility of developing the strength which makes a resin/glass laminate tough. If the glass was powdered it would be about as good as talc or slate powder; it would not have the high-tensile property of a fibre.

MR. G. VIVIAN DAVIES: Some time ago I was interested in the manufacture of glass-fibre pipes, and I investigated a very simple process. In this, hanks of glass-fibre were drawn through a bath of liquid plastic and wound on a mandrel, the hanks

traversing the mandrel in both directions. The mandrel was then removed and the pipe produced on it cured in an electric oven. This seemed a very simple process and tests by recognized testing authorities showed the pipe as being resistant to corrosion from a variety of acids and other corrosive liquids and gases. One of the claims made for the process was that the machine, which was of simple construction, could be transported by air together with the raw materials, so that pipes could be made in outlying parts of the world like the Middle East. It was claimed that in this way it would be very much cheaper than transporting steel pipes from this country or America. I know that this company got a trial order from one of the oil companies, but they never seemed to get anywhere with the process. One explanation I have heard was that after prolonged use the layers of fibre of which the pipe was made up tended to slide and cause distortion. I wonder if the lecturer can offer any other explanation for the lack of development in fibre-glass tubes? The one I saw had been tested to 2,000 lb./square inch.

THE LECTURER: In the early days of an industry like glass-fibres people are often tempted to make over-optimistic statements. Yet experience shows that by the time you have really tried to make an end product which is as useful in respect of service and cost as the one which has probably been in the market for years, you find that it is more tricky than at first people are inclined to think. So it is, I suspect, with the manufacture of reinforced tubing from glass fibres and resin. As regards transporting a pipe-making plant and making the pipes *in situ* in the Middle East, I should not be surprised if it were just about as difficult, in the long run, to produce good cheap plastic pipes in the Middle East that way, as to produce good steel pipes by transporting a steel tube manufacturing plant to the Middle East. Perhaps that is an exaggeration, but it is the order of difficulty that I really want to convey to you. We have a number of first-class tube-makers trying to make reinforced plastic pipes, because of course, there is a threat to some applications of steel tubes and they naturally want to be in the lead when glass-reinforced tubes develop. Porosity is perhaps the main reason why tube-making is not an immediate success, though it will certainly be solved soon.

MR. K. B. ROSS: I lately have come to own a house of my own and specified that the insulation in my roofs should be glass-fibre. I was quite amazed to find that the only way to get the proper laying of glass-fibre was to spend my weekends doing a quarter of my loft in order to demonstrate the method to the local contractor. Then I wanted my hot-water pipes insulated and I found that the local heating and ventilating engineer said that there was no need to insulate the pipes, because a lack of insulation was needed to cause circulation. I pointed out to him that this was not the case and I insisted on glass-fibre pre-formed sections being used. I feel it is all very well talking about lifeboats and all the rest, but why not just get down to the simple things of life which seem to acquire so much attention, and which I should have thought would have been so lucrative, like insisting that heating and ventilating engineers and the like use glass-fibre insulation, that they know how to lay glass-fibre in a loft, and so on? I wonder whether Mr. Hudson Davies has any comments on this?

THE LECTURER: Well, I think my old friend Mr. Ross went straight from Abadan to Warrington, both of which are perhaps relatively remote places and so we have not caught up with them yet! Seriously, we are most concerned with the problem he has raised. There is every evidence that people really are waking up to the importance of insulation now. We are having to go through the phase of changing over from direct relations with customers to indirect ones through stockists and merchants, and there is a big job of education to be done when you take that step. We are in the

middle of it now. We are, on the whole, going in the direction of making it easier for Mr. Ross to insulate his next house by packing the glass-wool insulation in more convenient forms.

MR. A. LEIGH: Is it not true that the fibres, instead of being solid rods, are in fact tubes and therefore moisture could percolate through them so that components used for high-voltage insulation would weaken or show deterioration in service?

THE LECTURER: Some of the fibres are tubes. You can photograph them and see the holes through them. The hole gets there because there was a bubble in the glass which, when drawn out, became a tube. We are always trying to get rid of what we call 'seed'—that is bubble in the glass—because the usual effect is to cause the filament to break in the drawing process. Most bubbles have this result, a very few get pulled out into these tubular fibres without breaking. So that a tubular filament is rare, and as bubbles themselves are rare, it is only a very small fraction of the length of the eight miles of a continuous filament that you will find a hollow or tubular form. Therefore, although you can frighten yourself stiff by looking at slides that show tubes instead of solid filaments, and think about water getting into the laminate, in fact, it is not important.

MR. H. J. POLLARD (Bristol Aircraft, Ltd.): The lecturer did not mention one extremely important matter relating to glass-fibres: that is, stiffness; the great specific strength of glass-fibres is, of course, of much importance but so also is specific stiffness.

As has been indicated, aircraft engineers are extremely interested in laminates made from glass-fibres. There is, in the Bristol *Britannia*, approaching 3,000 lb. finished weight of strong fibres, some of asbestos but mostly glass. There is also well over 30,000 lb. weight of aluminium alloy in the structure. It is of interest to consider if these weights will ever be reversed, at any rate in part.

There can be no question of that until glass-fibre laminates are used extensively in primary structure, and they cannot be so used until much stiffer material is available, that is, material having a much higher value of Young's Modulus than the present figure, there cannot be any question of decreasing the stiffness or increasing the per cent structure weight of aircraft—the opposite is the constant objective, and very inferior structures would result if present fibres were used for the purpose.

It might be asked: why then bother about glass laminates for aircraft? The great interest arises from the fact that the fatigue strength of glass-fibre laminates is superior to that of aluminium alloy, while its notch sensitivity in fatigue is very much less. All this means aircraft of longer life. In the light of present knowledge, I would not say 'safer', since the safe life of a light-alloy aeroplane is known, but the life of an aeroplane constructed from glass laminates of the future should be indefinite and no undue concern will be occasioned by a few scratches and that kind of thing. For the engineers present I would say that the Stress Endurance (S/N) curves for aluminium are asymptotic to zero, but not so with glass laminates; extensive investigations on fatigue strength are well under way and the S/N curves are asymptotic to a substantial percentage of the Ultimate Tensile Strength. I expect still better figures for high modulus glass.

Again, the easy mouldability of glass laminates would mean the much quicker manufacture of aircraft, particularly prototypes, than is possible with present materials and methods, and would enable refinements in design to be achieved with consequent weight savings, which cannot be now obtained except at great expense.

In consequence of these things, not only can a revolution in aircraft structure be expected when higher modulus fibres become commercially available, but in connection with a larger number of other purposes as well. Mr. Hudson Davies' company is very much alive to that, and moreover is striving to overcome the very real difficulties

that remain. I have not the slightest doubt of the ultimate success of the lecturer and his colleagues on this fundamental matter of stiffer fibres.

I disagree with the lecturer's statement that car-body manufacture in glass-fibre laminate can only relate to small production, which does not merit huge tooling costs essential to the cheap mass-produced body in metal. On the contrary, I am sure that automation for mass-produced glass-fibre laminate bodies is not so very far away: my opinion is based on much experimentation on the matter on a pilot plant in Bristol Aircraft Ltd.'s factory. Such automation is far more complete than anything I have ever seen in a car factory.

MR. G. MACKENZIE JUNNER: I noticed that the lecturer rather decried the use of glass-fibre clothing. About seventy years ago, my mother went to a ball at the Palace of Holyroodhouse in a dress of what is now called glass-fibre but was then known as woven spun glass. I do not know how long the dress lasted before it fell off or broke to pieces. At the time, however, my mother was, I believe, presented to Queen Victoria. So that the Queen may have had at least a glance at a dress of glass-fibre!

MR. OVE ARUP, C.B.E.: Mr. Hudson Davies mentioned that strength of glass-fibre was reduced from 200 tons per square inch to eighty. I would like to ask if there is any chance of counteracting this reduction, or is there any chance of using glass-fibre for cables in pre-stressed concrete? It would be very important in view of its fireproof and durable qualities if it could be so used.

THE LECTURER: I am going to ask our Development Manager, Mr. de Dáni, if he would kindly answer that question.

MR. DE DÁNI: The figure of 200 tons per square inch refers to the strength of single fibres tested in the laboratory immediately after they are drawn. The eighty tons per square inch is the strength of the commercially-produced strands composed of 204 single fibres. There is no reason to fear any further appreciable loss in strength, though some slight reduction may take place due to abrasion between the fibres in subsequent textile processing. This figure of eighty tons per square inch is more than ample for most applications.

Some investigations into both uses mentioned have been carried out and the results are not without promise.

THE CHAIRMAN: On your behalf I would like to thank Mr. Hudson Davies for the paper; to say that it has been a very interesting one is a considerable understatement. It is true to say we have had a very considerable privilege. It is always nice to be taken into somebody's confidence, to be told something that everybody does not know. We have been given a very good glimpse of the beginning of the glass-fibres industry, of its middle period of growth, and we have been given what I thought was a most exciting sketch of what lies ahead in the next decade or so. We are indeed very grateful to you, Mr. Hudson Davies, for the paper you have read to us. In addition to the solid information that we have gained I am sure that all of us have been stimulated by the story and thrilled by the fact that these exciting developments in industry are going on around us to-day, at a time when a casual look at the front page of quite a lot of newspapers would suggest that this country is approaching the down and out. Nothing could be further from the truth and we have had a very interesting demonstration of that this afternoon. Thank you very much for a most interesting and inspiring paper.

A vote of thanks to the Lecturer was carried with acclamation; and, another having been accorded to the Chairman, the meeting then ended.

THE STORY OF PANTOMIME

A Dr. Mann Juvenile Lecture

by

W. MACQUEEN-POPE

Monday, 7th January, 1957

Young people to-day have far more entertainment than they had when I was young—we had no radio, films were only just coming in and we knew nothing at all about television; the gramophone was something in the nature of a toy. We had to amuse ourselves—and we managed to do so. But we had what were known as 'treats'—I do not suppose you have such things now—and one of the greatest of those treats was an annual visit to the Pantomime, eagerly looked forward to and long remembered. It had its drawbacks, of course, because it hung over our heads like a threat. If we were not good boys and girls, we were told 'All right—no pantomime for you'. That threat was always with us, although we knew it would never be enforced. Grown-ups are such unpredictable beings—and a visit to the Pantomime was so important. And, indeed, Pantomime is a thing of great importance. Let nobody, youngster or adult, rate it lightly. It is really important. To begin with, it is probably the oldest form of entertainment known. It has roots deep in pre-history. Nobody quite knows how it began, but what it really is is clearly known. Pantomime is the mid-winter revel of the people—which is always played in mid-winter. It is more than possible that some old chief of pre-historic days, noticing that the spirits of his people were low when the nights were very long and the days very short—when there was little time for them to hunt or go to war—decided to hold a great feast and tribal dance around the communal fire, and so pantomime was born. That is not a flight of fancy, it is almost certainly a fact. For pantomime, in some form or another, has always been with us. The ancient Greeks knew it well—its very name is derived from a Greek word meaning 'I imitate all', for pantomime does not mean miming, or dumb show.

The ancient Romans knew it well. Indeed, there is a link to-day between their times and the modern pantomime. The mid-winter feast of the Romans was *Saturnalia*—which was held at the time when we now celebrate Christmas. It was a crazy, topsy-turvey affair when the world went upside down, when women dressed as men and men as women, when slaves became the masters and masters waited on their slaves. All that is visible in pantomime to-day—and is the reason why the Principal Boy is always played by a girl and the principal female character—the Dame, as it is called, is played by a man. Also in all good pantomimes, all Barons, Earls, Kings and Queens are desperately hard-up and afraid of their servants. All that is derived directly from the Roman *Saturnalia*. But the Romans, who took pantomime from the Greeks, as they took so many

other art forms, debased it badly. Their pantomimes became disgraceful performances of a most prurient nature, performed by slaves; and were the cause for the Theatre of Rome being closed down entirely by the early Christians when they came into power. For some centuries there was no theatre—in the collective sense—at all. And then the Church, which had closed it down, called it back again. It was found that an excellent way to propagate the teachings of the Gospel amongst the great illiterate masses of those days was by means of an appeal to the eye and the ear. So they invented the very beautiful Mystery, Morality and Miracle plays—many of which we still play to-day. Now those were not pantomimes, they were religious plays—although one of them about Noah was full of excellent knockabout fun—but yet a tradition of those old religious dramas is preserved as a tradition in pantomime to-day.

In all proper pantomimes, the Demon King must only enter from the left-hand side of the stage—the prompt side facing the audience—and stay there; and the Fairy Queen from the right-hand side—and she must stay there too. That is a link with those old mystery plays in which the left-hand—or sinister-side of the stage was that of the Power of Evil, and the right-hand side the territory of the Good. And the message of all pantomimes is the same—the never ceasing fight 'twixt right and wrong, with Virtue, of course, always winning.

Pantomime has always been changing. It was quiescent for a long time, but it came to England in the reign of James I, only it was not pantomime. It came here as a form of the *Comœdia del' Arte* from Italy, brought over by a Venetian comedian named Arlecchino, who was a clown. His name still exists—but no longer as clown—as Harlequin. And Arlecchino, in himself, provides a very nice little bit of evolutionary history, showing how pantomime, which changes apparently so much, still sticks to basic facts.

Arlecchino's make-up is worthy of study. He was a gaunt, cadaverous-looking man, with a very pale face plentifully smirched with dirty smudges; he had loose, baggy clothes, much the worse for wear and especially baggy, patched breeches. He had large, splay feet, and in his hand he carried a staff. That costume, down the ages has changed, and yet remained the same.

In due course Harlequin, to whom Arlecchino had given his name, became the principal character in pantomime. His costume? Well, the pale face had gone, but the black smudges became the black mask of invisibility—which Harlequin always wears. When he turns it up, he is visible, when he turns it down he is invisible. The patches on Arlecchino's clothes became those lozenges which bedeck the Harlequin and for many years the Harlequin wore loose coats and trousers, all lozenged—it was not until the beginning of the nineteenth century that Byrne, a very famous Harlequin, adopted the skin-tight clothes of to-day, and of course kept the lozenges. The splay feet had gone but the staff had become the magic sword of lath which Harlequin wielded so potently.

And then, the Clown got on top. The greatest clown of all time, Joe Grimaldi, displaced Harlequin from his throne as King of pantomime and took it himself. The clown now rules—the earthy methods of low comedy banished romance—

and strangely enough this reversal coincided with the Industrial Revolution in this country. Utility and down-to-earth methods had conquered romance. Grimaldi was very great indeed. He has bequeathed his name to all clowns who have succeeded him—for the name of every clown is 'Joey'—after Joe Grimaldi.

And what was Grimaldi's make-up? Almost a throwback to that of Arlecchino. He had the pale face—the dead white of the clown achieved by what we call oxide of zinc—the black marks had taken on colour and become half moons and little circles on the white face. The clothes were very similar and the patches were of red and blue and the breeches had become things like Elizabethan trunks. The splay feet were simulated, and if the staff had gone it was replaced by the much more powerful red hot poker. And that is still the clown to-day, when you come across him (I am speaking of pantomime stage clowns, not the circus variety which are very different). The original elements of the make-up are still there. And consider for a moment the make-up of the greatest clown of modern—and may be of all—time, Charlie Chaplin. There is the pale face, the black marks have shrunk to the tiny toothbrush moustache, but they are there. The ragged, baggy patched breeches and clothes are there—the splay feet are there—and the staff has become the classic little cane. And so the clown goes on down the centuries for nearly 400 years.

The British liked the *Comœdia del' Arte* very much, and in that nice little acquisitive way for which they have—up to now—been so famous, they just took it and made it their property. It became British. They altered it, of course, to suit their own tastes and ideas, and soon very little of the Italian source was apparent at all—except Arlecchino's name anglicized into Harlequin, and some of the characters, who had forsaken their foreign origin and become more British than the British themselves. It existed in that form for roughly 100 years and then something happened. The seed from which our modern pantomime evolved—for pantomime like all else is subject to evolution—suddenly blossomed forth at Theatre Royal, Drury Lane, the oldest and most famous theatre in the world—in the year 1702. This was a crazy, topsy-turvey upside-down piece of fun, full of knockabout, clowning, singing and dancing, and was called *The Tavern Bilkers*—written by John Weaver, a dancing master of Shrewsbury. The central character was, of course, Harlequin.

Although at first this did not create a sensation, it was frequently revived and became immensely popular, and it was the origin of modern pantomime, containing all those ingredients which pantomime must have—topsy turviness, craziness, and topicality. For unless a pantomime has those things, it is not a pantomime. Do not make a mistake, such things as *Peter Pan*, *Where the Rainbow Ends* and the like, magnificent entertainments as they are, are not pantomimes. They are children's plays—an entirely different thing.

GENERAL NOTES

PEEP-SHOW OF THE PAST

It is curious what very little notice has been taken of the silent revolution which, in our time, has transformed the nursery toy cupboard. In our childhood, forty years or so ago, there appeared to be no sign that our sturdy wooden toys—the rocking horse, the doll's house, the heroically resisting fort on which lead soldiery might be deployed—would ever cease to satisfy, ever cease to be acceptable to fresh youngsters, when we had become oldsters. Yet what child to-day is ever seen whipping a top? The top has disappeared along with all those flashing hoops, ubiquitous in the Broad Walk only forty years ago. Doubtless no young reader of a comic, imagining himself a Space Captain, could ever think of amusing himself with such simple and terrestrial diversions.

Yet the interesting thing is that parties of children do go very often, and with evident enjoyment, to look at over four thousand 'Wooden Bygones', as Mr. and Mrs. Pinto have termed their unique collection. This assemblage, patiently and discerningly acquired by Mr. Edward Pinto ever since he was a boy, and arranged to-day in imitation shop windows at Oxhey Woods House, near Northwood in Middlesex, has been on view to the public for the past two years. People have come from all parts of the world to examine these wooden objects, fashioned in earlier centuries, and providing—as *The Manchester Guardian* has said—'a peep-show of our forebears' way of life'.

Apart from its obvious fascination for social historians, this immense hoard is most valuable for its indication of the evolution of design in all manner of objects, common and uncommon, ranging from Elizabethan spice boxes to kitchen utensils of more recent times. Like Peter Standish, one breathes another atmosphere, and seems to hear forgotten street cries, as one peers into an early toy shop, a tobacconist's, a tool shop, an apothecary's, or that emporium filled with exquisite examples of the wood mosaic which Tunbridge Wells produced in the Victorian age.

Oxhey Woods House is very accessible, not far from either Northwood Station or Carpenders Park Station. The admission charge is as reasonable as its normal hours of opening on Wednesday, Thursday, Saturday and Sunday afternoons, every week from April until the end of September. It is the most agreeable and instructive outing imaginable.

NEVILE WALLIS

F.I.D.E.M. CONGRESS

The seventh Congress of the Fédération Internationale des Editeurs de Médailles (F.I.D.E.M.), is to be held in Paris from 23rd to 28th May, 1957. Fellows will remember that F.I.D.E.M. was associated with this Society in arranging the exhibition of European Medals held at the Society's House and elsewhere in this country in the summer of 1955. The Congress, membership of which is open to those Fellows of the Society who are interested, will consist of a series of lectures, discussions and social occasions, and will include an international exhibition of contemporary medals.

Full particulars and application forms are obtainable from Mr. D. F. Spink, Spink & Son, Ltd., 5, 6 and 7 King Street, St. James's, S.W.1. The official closing date for the receipt of completed applications in Paris is 1st May, but as a special concession this is extended to 10th May for Fellows of the Society wishing to attend.

'ARCHITECTURE IN FINLAND' EXHIBITION

The first exhibition of Finnish Architecture to be shown in this country is at present on view at the Royal Institute of British Architects, where it will remain

until 2nd May. The exhibition, which is sponsored by the Museum of Finnish Architecture in Helsinki, is composed mainly of photographs illustrative of the modern art of building in Finland, and also contains a small introductory section of work executed in the 1930s. Many examples of the work of Professor Alvar Aalto, Hon.R.D.I., are included, with some of the latest furniture designed by him. The exhibition is open on Mondays to Fridays from 10 a.m. to 7 p.m., and on Saturdays from 10 a.m. to 5 p.m. Admission is free.

FURNISHING EXHIBITION

'Make or Mar?', an exhibition of modern furnishing sponsored jointly by the Design and Industries Association and *The Sunday Times* is at present on view in the passenger hall at Charing Cross Underground Station, where it will remain until 4th May. In two rooms designed by Misha Black and Margaret Casson contrasting arrangements, both employing good modern furnishing and interior decoration, show the pitfalls which, in the opinion of the D.I.A., are to be avoided in the use of the modern idiom.

The exhibition is open daily (except Sundays) from 10 a.m. to 10 p.m. Admission is free.

TRAVEL GRANTS FOR ARTISTS

The English-Speaking Union of the Commonwealth announces the offer of three travel grants to enable artists between thirty and fifty years of age to make study tours of the United States. Practising artists, designers, architects, museum curators, and teachers and editors in these fields will be eligible for the grants which will make visits of up to ten weeks possible, between September, 1957, and June, 1958.

Full particulars and application forms are obtainable from the English-Speaking Union, 37 Charles Street, London, W.1. Closing date for applications is 11th June, 1957.

OBITUARY

FREEMAN WILLS CROFTS

We record with regret the death, at Worthing on 11th April, of Mr. Freeman Wills Crofts, the writer of detective fiction and creator of 'Inspector French'.

Freeman Wills Crofts was born in 1879 in Dublin. He was educated at the Methodist and Campbell College, Belfast, and trained as a civil engineer, after which he held a number of responsible posts with the railways. It was not until an enforced rest, following an illness in his late thirties, that he took up writing. His first detective novel, *The Cask*, was published in 1919 and in 1929 he gave up his engineering career and devoted himself entirely to writing. Among his long series of works were *Inspector French and the Starvel Tragedy*, *Found Floating*, and *Enemy Unseen*; while among his writings were also a religious work, *The Four Gospels in One Story*, and several short plays broadcast by the B.B.C.

Freeman Wills Crofts was elected a Fellow of the Society in 1939.

NOTES ON BOOKS

DUTCH STILL-LIFE PAINTING IN THE SEVENTEENTH CENTURY. *By Ingvar Bergström. Translated by Christian Hedström and Gerald Taylor. Faber*, 1956. 84*s*

An intensive study of Dutch still-life painting throws light on more than a particular *genre* in the history of art, and illumines as well the whole field of Dutch painting. The genius of a people which produced so many painters in the first rank in the surprisingly short period of scarcely more than fifty years at the end of the sixteenth

and the beginning of the seventeenth centuries, expressed itself with particular force in the painting of still-life. The work, which is already of international repute, and of which this is a recent translation into English, deals with various subjects in the art of painting which have the general title of still-life. In fact, it was the 'still-life' attitude to painting which inspired some of the finest work of the Dutch School in other *genres*. That gives what might in another instance seem an academic isolation of a specialized field of painting a very general appropriateness and interest.

Dr. Bergström is a research fellow at the University of Gothenburg and has devoted thirty years of study to this field. The fruit of that study is this detailed examination and analysis of the work of most of the Dutch painters of importance in that field. He traces the origins of the 'school' in late illuminated manuscripts, in the easel painting of the Netherlands and in the gradual separation of this particular subject matter from the religious painting of the previous centuries, in the same way as landscape was separated. Dr. Bergström indicates the symbolism which determined the selection of objects, such as the skull or the burnt-out candle of the *Vanitas* still-life, but this symbolism was surely secondary to the love of artists for the things themselves and the opportunity which that afforded for splendid fantasies of decoration and the sort of *trompe d'oeil* which their patrons favoured. That and the wealth of the society in which the artist lived—Amsterdam was the wealthiest city in the world at the time—were partly responsible for such an outburst of genius.

The subject is divided into types of still-life, for example, the Breakfast Piece, the Fower Piece, the *Vanitas* still-life, and so on, which represent a real distinction of subject matter, but perhaps one may regret that such a method, with all its advantages, makes it harder in some cases to see an artist's *œvre* as a whole.

Each painter is introduced with the available biographical detail, often slight, and this is followed by a detailed analysis of his known work. Among these painters we find those who are famous for their work in other fields and those who are known as painters of still-life, de Gheyn, Ambrosius Bosschaert, van der Ast, Willem Claesz. Heda, de Heem, Willem van Aelst, Van Beyeren and Willem Kalf. The book is lavishly illustrated with eight colour plates of high standard and 239 monochromes, which enable the analysis of the majority of the pictures treated to be followed with ease. It will remain for the student and general reader alike a book to be read and referred to with pleasure.

DAVID BELL

SHORT NOTES ON OTHER BOOKS

THE ENGLISH TOWN IN THE LAST HUNDRED YEARS. *By John Betjeman. The Rede Lecture*, 1956. *Cambridge University Press*, 3*s* 6*d*

Mr. Betjeman's delight in the variety of English architecture, and his fears for the appearance of our towns in the present time, are vividly conveyed in the 24 short pages of this reprint of the Rede lecture delivered in Cambridge, and dedicated 'to whoever is Minister of Fuel and Power, and particularly his permanent officials in the hope that they will save what is left of England's beauty'.

THE HAVEN-FINDING ART: A HISTORY OF NAVIGATION FROM ODYSSEUS TO CAPTAIN COOK. *By Professor E. G. R. Taylor. London, Hollis and Carter*, 1956. 30*s*

In tracing the story of man's inventiveness and resource in finding his way 'blind' across the seas, the author follows successive lines of invention or advance. The history is continued down to the voyages of Captain Cook, the first navigator to sail with the full equipment of sextant, compass and chart, chronometer and nautical almanac. The book is illustrated with many line blocks and half-tone plates.

FROM THE JOURNAL OF 1857

VOLUME V. *1st May*, 1857

LONDON TRAFFIC CONGESTION

The brightest intellects of the country and ablest engineers of the land, are devising means by which all parts of the civilized globe shall be placed in immediate contact. The harnessed lightning, obedient to our will, is delivering every moment, at every central seat of commerce, the course of Exchange on Paris, or the price of Consols in Capel Court; but how to shorten the overland route from Charing Cross to Whitechapel is left to a few enthusiastic private persons, who are, I fear, looked upon as lunatics, the matter seemingly being abandoned as hopeless, while the evil is increasing day by day.

So thoroughly has the tedious traffic of the streets become ground into the true Londoner's nature, that, to shorten his course from Piccadilly to the Bank, would be to rob him of a vested right or a natural privilege. If a railway train from Aberdeen or the Land's End arrives in London five minutes behind its time, the indignant traveller vents his spleen and writes a letter to *The Times*, but your do-collar'd occupant of the knifeboard of a Clapham omnibus, will stick on London-bridge for half-an-hour with scarcely a murmur.

Some Activities of Other Societies and Organizations

MEETINGS

MON. 29 APR. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. G. W. Hosie, D. Kerr and W. Kiryluk : *Radio in air-sea rescue.*

Geographical Society, Royal, Kensington Gore, S.W.7. 8.30 p.m. Professor J. Steers and Professor L. Dudley Stamp : *South American prospect.*

TUES. 30 APR. Economics and Political Science, London School of, Houghton Street, W.C.2. 5.0 p.m. Dr. F. A. Vali : *The Hungarian revolution and international law.*

Metals, Institute of, at Church House, Great Smith Street, S.W.1. 2.30 p.m. Dr. O. Kubaschewski and Dr. C. Edeleanu : *The metal physics of corrosion and oxidation.*

William Morris Society, at the Art Workers' Guild, 6 Queen Square, W.C.1. 7.30 p.m. Joseph Dunlap : *William Caxton and William Morris.*

WED. 1 MAY. Petroleum, Institute of, at 26 Portland Place, W.1. 5.30 p.m. Dr. A. Lee, J. Nicholas and P. Leaver : *The properties and use of bitumen in road making.*

Physical Society, at the Institute of Opthalmology, 45 Lincolns Inn Fields, W.C.2. 3.30 p.m. I. M. Gibson : *Chromatic adaptation in colour defective observers.*

THURS. 2 MAY. Anthropological Institute, Royal, 21 Bedford Square, W.C.1. 5.30 p.m. Mrs. J. M. Jones : *The Wayang Kulit of Java and Bali : with particular reference to study in England.*

Metals, Institution of, at the University, Leeds, 2. 7.30 p.m. J. Meakin : *Some aspects of creep.*

FRI. 3 MAY. Radio Engineers, British Institution of, at the Ministry of Supply College of Electronics, Malvern, Worcs. 7.0 p.m. H. Whitfield : *Marine radar.*

MON. 6 MAY. Engineers, Society of, at The Geological Society, Burlington House, W.1. 5.30 p.m. Sir Graham Sutton : *Meteorology to-day.*

TUES. 7 MAY. Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. F. W. Meredith : *Invention and nature.*

WED. 8 MAY. Physical Society, at the Imperial College, S.W.7. 5.30 p.m. E. Halfpenny : *Tonal evolution of wood-wind instruments.*

Tropical Medicine and Hygiene, Royal Society of, at 26 Portland Place, W.1. 5.30 p.m. Professor C. de Duve : *The present status of Glucagon.*

THURS. 9 MAY. Chemical Society, Burlington House, W.1. 7.30 p.m. Professor O. Hassel : *Structural evidence regarding the solid addition-compounds of Ethers and Amines with Halogens and other Molecules acting as Electron Acceptors.*

Electrical Engineers, Institution of, Savoy Place, W.C.2. 5.30 p.m. H. J. Miller : *The world's copper resources.*

FRI. 10 MAY. Road Transport Engineers, Institute of, at South Wales Institute of Engineers, Park Place, Cardiff. 7.0 p.m. C. H. Rowley : *The service methods and construction of commercial vehicles.*

OTHER ACTIVITIES

NOW UNTIL SAT. 4 MAY. Design and Industries Association, at 13 Suffolk Street, Haymarket, S.W.1. Exhibition : *Make or mar?*

NOW UNTIL TUES. 7 MAY. Imperial Institute, South Kensington, S.W.7. Exhibition : *Paintings by Albert Tucker.*

NOW UNTIL SAT. 11 MAY. The Royal Drawing Society, at the Guildhall Art Gallery, Guildhall Yard, E.C.2. Exhibition : *The children's Royal Academy.*

NOW UNTIL TUES. 14 MAY. The County Hall, Westminster Bridge, S.E.1. Exhibition : *Art in London schools.*

NOW UNTIL WED. 15 MAY. Exhibition of paintings from the Musée d'Art Moderne, Paris, at the R.B.A. Galleries, Suffolk Street, S.W.1.

NOW UNTIL SAT. 18 MAY. Exhibition of specially commissioned work, at The Crafts Centre, 16–17 Hay Hill, Berkeley Square, W.1.

NOW UNTIL SAT. 18 MAY. Exhibition of drawings by Ingres, at the Arts Council, 4 St. James's Square, S.W.1.

NOW UNTIL SAT 18 MAY. Exhibition of 100 recent ceramics of Picasso, at the Arts Council, 4 St. James's Square, S.W.1.

NOW UNTIL SUN. 26 MAY. Exhibition of paintings from the Solomon R. Guggenheim Museum, New York, at the Tate Gallery, Millbank, S.W.1.

NOW UNTIL FRI. 31 MAY. Royal Society of Health, 90 Buckingham Palace Road, S.W.1. Exhibition : *Atoms and health.*

MON. 29 APR. UNTIL SUN. 5 MAY. Imperial Institute, South Kensington, S.W.7. Films : *Australian Diary ; Prince of Palms—Malaya ; Bulawayo—Rhodesia ; Scientists in the Antarctic.*

LIBRARY ADDITIONS

EXHIBITIONS

HALSINGBORG, 1955—International exhibition of architecture, industrial design, home furnishings and crafts. Council of Industrial Design. Industrial Design in Great Britain, with a complete catalogue of the British exhibit at H.55. *London, Council of Industrial Design*, 1955.

LONDON, 1956—Exhibition of Anglo-Jewish art and history. Catalogue of an exhibition of Anglo-Jewish art and history. *London, Victoria and Albert Museum*, 1956.

LONDON, 1956—This is tomorrow. *London, Architectural Design*, 1956. (Catalogue of the exhibition.)

LIBRARIES, MUSEUMS AND SOCIETIES

BRITISH galleries of art—*London, G. and W. B. Whittaker*, 1824. Gift of Mrs. Winifred Nicholls.

*BRITISH RECORDS ASSOCIATION—List of record repositories in Great Britain. *London. British Records Association*, 1956.

JAMESON, MRS.—A companion to the most celebrated private galleries of art in London. *London, Saunders and Otley*, 1844. Gift of Mrs. Winifred Nicholls.

ROBINSON, J. C.—Italian sculpture of the middle ages and the period of the revival of art, a descriptive catalogue of the works forming the above section of the museum (South Kensington), with additional illustrative notices. *London, Chapman & Hall*, 1862. Gift of Mrs. Winifred Nicholls.

*SCIENTIFIC and learned societies of Great Britain—A handbook compiled from official sources. 58th Ed. *London, Allen & Unwin*, 1956.

WALPOLE, HORACE—A catalogue of the classic contents of Strawberry Hill collected by Horace Walpole. *London, George Robins*, 1842.

ENGINEERING, TRADE AND INDUSTRY

URE, ANDREW—Ure's dictionary of arts, manufactures and mines; containing a clear exposition of their principles and practice; edited by Robert Hunt. *London, Longman, Green, Longman & Roberts*, 1860. 5th edition.

INDUSTRIAL AND COMMERCIAL ART AND DESIGN

DUTTON, RALPH (STAWELL)—The Victorian home: some aspects of nineteenth-century taste and manners. *London, Batsford*, 1954.

GIBBS, W.—The handbook of architectural ornament illustrating and explaining the various styles of decoration and intended as a guide to designers and draughtsmen. *London, Atchley & Co*, (1866). Gift of Mrs. Winifred Nicholls.

GREAT BRITAIN, House of Commons—Report from the select committee on arts and their connection with manufactures; with the minutes of evidence, appendix and index. *London, House of Commons*, 1836.

GLOAG, JOHN (EDWARDS)—Georgian grace: a social history of design from 1660 to 1830. *London, Black*, 1956.

HOBBS, ERIC—Drawing from advertising. *London, Studio Publications*, 1956.

HUNGARIAN ETHNOGRAPHICAL MUSEUM—Hungarian decorative folk art. *Budapest, Corvina*, 1954. Presented by Mr. F. A. Mercer.

JONES, BARBARA—English furniture at a glance, written and illustrated by Barbara Jones. *London, Architectural P.*, 1954. Presented by Mr. F. A. Mercer.

RASMUSSEN, STEEN EILER—Danish textiles. *Leigh-on-Sea (Essex), F. Lewis*, 1956. Presented by Lord Nathan.

* Books marked with an asterisk are part of the reference library and not normally available for loan.

ARCHITECTURE AND BUILDING (INCLUDING TOWN PLANNING)

BETJEMAN, JOHN—The English town in the last hundred years. *Cambridge, Cambridge U.P.*, 1956.

FRY (EDWIN) MAXWELL, and DREW, JANE (BEVERLY)—Tropical architecture in the humid zone. *London, Batsford*, 1956.

FÜRST, VIKTOR—The architecture of Sir Christopher Wren. *London, Lund, Humphries*, 1956.

GROPIUS, WALTER—Scope of total architecture. *London, Allen and Unwin*, 1956.

HARADA, JIRO—Japanese gardens. *London, Studio publications*, 1956.

LARNED, WALTER CRANSTON—Churches and castles of mediæval France. *London, Sampson Low, Marston and Co.*, 1895. Gift of Mrs. Winifred Nicholls.

LAVEDAN, PIERRE—French architecture (translated from the French). *London, Penguin Books*, 1956.

MUMFORD, LEWIS—From the ground up; observations on contemporary architecture, housing, highway buildings, and civic design. *New York, Harcourt, Brace and Company*, 1956.

POTTER, MARY KNIGHT—The art of the Venice academy, containing a brief history of the building and of its collection of paintings as well as descriptions and criticisms of many of the principal pictures and their artists. *London, George Bell and Sons*, 1906. Gift of Mrs. Winifred Nicholls.

READ, HERBERT—*Editor* Unit 1. The modern movement in English architecture painting and sculpture. *London, Cassell and Co.* (1934).

ROWE, VIVIAN—Royal châteaux of Paris. *Putnam*, 1956. Presented by Mr. F. A. Mercer.

SINGLETON, WILLIAM A. *Editor*. Studies in architectural history, vol. 2. *London, St. Anthony's P.* 1956.

SOMAKE, ELLIS EDWARD, *and* HELLBORG, ROLF—Shops and stores today: their design, planning and organization. *London, Batsford*, 1956.

CRAFTS AND LIGHT MANUFACTURES

CUSHION, JOHN PATRICK *and* HONEY, WILLIAM BOWYER—*Compilers*. Handbook of pottery and porcelain marks. *London, Faber*, 1956.

FINLAY, IAN—Scottish gold and silver work. *London, Chatto and Windus*, 1956.

GERSPACH—La mosaïque. *Paris, A. Quantin* (188?).

GUTTERY, DAVID REGINALD—From broad-glass to cut crystal: a history of the Stourbridge glass industry. *London, L. Hill*, 1956.

HUGHES (GEORGE) BERNARD—The story of Spode. *Stoke-on-Trent, W. T. Copeland and Sons*, 1950.

KEMP, DOROTHY—English slipware: how to make it; with an introduction by Dorothy Kemp. *London, Faber*, 1954. Presented by Mr. F. A. Mercer.

A RENASCENCE of the Irish art of lace-making—*London, Chapman and Hall*, 1888.

TAYLOR, GERALD—Silver. *Harmondsworth, Penguin Books*, 1956.

WILLIAMSON, HUGH—Methods of book design: The practice of an industrial craft. *London, Oxford U. P.* 1956. Presented by Mr. and Mrs. G. W. Williamson.

FINE ARTS (GENERAL)

ARNHEIM, RUDOLF—Art and visual perception: a psychology of the creative eye. *London, Faber*, 1956.

BALDRY, ALFRED LYS—Burne-Jones. *London, T. C. & E. C. Jack*, n.d.

BALDRY, ALFRED LYS—The life and work of Marcus Stone, R.A. *London, The Art Journal Office*, 1896. Gift of Mrs. Winifred Nicholls.

BERGSTRÖM, INGVAR. Dutch still-life painting in the seventeenth century; translated (from the Swedish) by Christina Hedström and Gerald Taylor. *London, Faber*, 1956.